

# WHAT IS CLAIMED IS:

1. A method for dispensing a build material in a flowable state from a dispensing device of a solid freeform fabrication apparatus to form a three-dimensional object, the method comprising the steps of:

providing at least one queue station for holding a plurality of discrete amounts of build material in a non-flowable state;

loading the plurality of discrete amounts of build material in a non-flowable state to the queue station, the discrete amounts of build material residing in the queue station in a random order;

delivering the discrete amounts of build material from the queue station to at least one hopper on the dispensing device;

changing the build material from the non-flowable state to the flowable state after delivery of the build material to the hopper;

moving the build material in the flowable state in the hopper to a receptacle of the dispensing device; and

dispensing the build material in the receptacle by the dispensing device in the flowable state in a layerwise fashion to form the three-dimensional object.

2. The method of claim 1 further comprising the step of:

providing an environment for the build material to return to the non-flowable state after being dispensed in the layerwise fashion.

3. The method of claim 1 wherein the step of delivering the discrete amounts of build material occurs in response to a low condition detected in the amount of build material held in the receptacle.

4. The method of claim 1 wherein the step of moving the build material in the flowable state in the hopper to the receptacle is accomplished by capillary action.

5. The method of claim 1 wherein the steps are separately performed for dispensing a support material, the support material forming supports for the three-dimensional object.

6. The method of claim 5 wherein the step of dispensing the build material and the step of dispensing the support material is performed by at least one ink jet print head.

7. The method of claim 5 wherein the steps are separately performed for a plurality of different build materials, each different build material being associated with a unique visual characteristic.

8. The method of claim 7 further comprising the step of including a color additive in each different build material to establish the plurality of different build materials.

9. The method of claim 8 wherein the color additives are indicative of the colors consisting of cyan, magenta, yellow, and black.

10. A build material feed system for a solid freeform fabrication apparatus, the build material having a non-flowable state and a flowable state, the apparatus having a dispensing device for dispensing the build material, the feed system comprising:

means for holding a plurality of discrete amounts of build material in a non-flowable state;

means for delivering the discrete amounts of the build material in the non-flowable state to at least one hopper on the dispensing device;

means for changing the build material from the non-flowable state to the flowable state after delivery of the build material to the hopper;

means for moving the build material in the flowable state in the hopper to a receptacle of the dispensing device;

means for dispensing the build material in the receptacle by the dispensing device in a layerwise fashion.

11. The build material feed system of claim 14 further comprising

means for detecting a low condition of build material held in the receptacle for controlling the delivery of the discrete amounts of build material to the hopper.

12. The build material feed system of claim 15 wherein the means for moving the build material in the hopper to the receptacle comprises a passage in the dispensing device, the passage being in communication between the receptacle and the hopper.

13. The build material feed system of claim 12 wherein the dispensing device has at least one discharge orifice in communication with the receptacle, the discharge orifice having a capillary force, and the passage comprises a capillary valve having an effective capillary force greater than the capillary force of the discharge orifice and the

receptacle of the dispensing device is maintained at sub-atmospheric pressure.

14. The build material feed system of claim 10 wherein the dispensing device comprises at least one ink jet print head having a plurality of discharge orifices.

15. The build material feed system of claim 14 wherein the dispensing device comprises at least two hoppers, at least one hopper adapted for receiving the build material to be dispensed to form the three-dimensional object, and at least another hopper adapted for receiving a support material to be dispensed to form supports for the three-dimensional object.

16. The build material feed system of claim 10 further comprising at least two dispensing devices, at least one dispensing device for dispensing the build material forming the three-dimensional object and at least one dispensing device dedicated to dispense a support material to form supports for the three-dimensional object.

17. The build material feed system of claim 10 wherein the dispensing device comprises a plurality of hoppers, each hopper being associated with a different build material having a unique visual characteristic and being delivered the build material indicative of the unique visual characteristic.

18. The build material feed system of claim 17 wherein the unique visual characteristic associated with the hoppers is color, and a color additive is provided in the different build materials delivered to the hoppers.

19. The build material feed system of claim 18 wherein the color additives are indicative of the colors consisting of cyan, magenta, yellow, and black.

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22. A solid freeform fabrication apparatus for forming a three-dimensional object in a layerwise fashion by dispensing a build material in a flowable state, the apparatus comprising:

a build environment having a build platform for supporting the three-dimensional object while it is being formed;

at least one dispensing device adjacent the build platform for dispensing the build material in the flowable state to form layers of the three-dimensional object, the dispensing device having at least one hopper for receiving the build material;

at least one queue station for holding a plurality of discrete amounts of build material in a random order, the material residing in a non-flowable state;

a motion means for moving the dispensing device and the build platform respectively when dispensing the build material;

a means for delivering the discrete amounts of build material from the queue station to the hopper;

a heating means in communication with the hopper for changing the build material from the non-flowable state to the flowable state; and

a computer controller for receiving object data descriptive of the three-dimensional object, the computer controller adapted for processing the data in order to control the apparatus when forming the three-dimensional object.

23. The apparatus of claim 21 wherein the dispensing device further comprises:

at least one receptacle for holding a volume of the build material in the flowable state; and

wherein the discrete amounts of the build material are delivered to the hopper in response to a low condition detected by the computer controller in the amount of build material held in the receptacle.

24. The apparatus of claim 23 wherein the dispensing device further comprises:

at least one discharge orifice in communication with the receptacle, the discharge orifice having a capillary force;

a passage in communication with the receptacle and the hopper, the passage including a capillary valve having an effective capillary force greater than the capillary force of the discharge orifice, the passage allowing the build material in the hopper that has changed to the flowable state to travel through the passage and into the receptacle; and

wherein the volume of build material in the receptacle of the dispensing device is maintained at sub-atmospheric pressure.

25. The apparatus of claim 24 wherein at least one hopper is adapted for receiving the build material to be dispensed to from the three-dimensional object, and at least one other hopper is adapted for receiving a support material to be dispensed to form supports for the three-dimensional object.

26. The apparatus of claim 22 further comprising at least two dispensing devices, at least one dispensing device for dispensing the build material forming the three-dimensional object, and at least one other dispensing device for dispensing a support material to form supports for the three-dimensional object.

27. The apparatus of claim 22 wherein the dispensing device further comprises a plurality of hoppers, each hopper being associated with a different build material having a unique visual characteristic and being delivered build material indicative of the unique visual characteristic.

28. The apparatus of claim 27 wherein the unique visual characteristic of the build material delivered to each hopper is color, and a color additive is provided in the different build materials delivered to the hoppers.

29. The apparatus of claim 28 wherein the color additives are indicative of any one or combination of the colors consisting of cyan, magenta, yellow, and black.

30. The apparatus of claim 29 wherein the dispensing device comprises a plurality of orifices in communication with the hoppers such that all the different build materials can be selectively dispensed to any coordinate in any layer on the three-dimensional object.



31. A method for delivering at least one unused material and removing waste material in a solid freeform fabrication apparatus to form a three-dimensional object, the method comprising the steps of:

delivering at least one container to a queue station, the container holding a discrete amount of material;

removing the discrete amount of material from the container;

delivering the removed material to a dispensing device;

dispensing the removed material from the dispensing device in a layerwise fashion to form the three-dimensional object;

producing waste material from the dispensed material; and,

depositing the waste material in a waste receptacle associated with the container for removing the waste material.

32. The method of claim 31 further comprising the steps of:

ejecting the container when substantially all of the material in the container has been expelled; and

replacing the ejected container with another container.

33. The method of claim 32 further comprising the step of:

curing the waste material in the waste receptacle.

34. The method of claim 33 wherein the waste material is cured by exposing the waste material to actinic radiation.

35. The method of claim 34 further comprising the step of:

closing the waste receptacle prior to ejecting the container.

36. The method of claim 31 wherein the steps are executed for dispensing a build material to form the three-dimensional object and for dispensing a support material to form support for the three-dimensional object, the build material and support material being held in separate containers.

37. The method of claim 36 further comprising the steps of:  
ejecting the containers when substantially all of the material in the container has been expelled; and  
replacing the ejected container with another container holding a discrete amount of material to be delivered to the dispensing device.

38. The method of claim 37 further comprising the step of:  
curing the waste material in the waste receptacle by exposing the waste material to actinic radiation.

39. The method of claim 38 further comprising the step of:  
closing the waste receptacle prior to ejecting the container.

40. A material feed and waste system for a solid freeform fabrication apparatus, the system comprising:

- means for delivering at least one container to a queue station, the container holding a discrete amount of material;
- means for removing the discrete amount of material from the container;
- means for delivering the removed material to at least one dispensing device;
- means for dispensing the material by the dispensing device in a layerwise fashion to form via a plurality of layers a three-dimensional object;
- means for normalizing the layers of the three-dimensional object wherein waste material is produced;
- means for depositing the waste material in a waste receptacle associated with the container.

41. The system of claim 40 further comprising:

- means for ejecting the container when substantially all of the material in the container has been removed.

42. The system of claim 41 further comprising:

- means for curing the waste material after the waste material is delivered to the waste receptacle.

43. The system of claim 42 wherein the means for curing the waste material cures the waste material by exposure to actinic radiation.

44. The system of claim 43 further comprising:

- means for closing the waste receptacle prior to ejecting the container.

45. The system of claim 40 further comprising:  
means for delivering at least one container to a support queue station, the container holding a discrete amount of a support material;  
means for removing the discrete amount of support material from the container;  
means for delivering the removed support material to the dispensing device;  
means for dispensing the support material by the dispensing device in a layerwise fashion to form supports for the three-dimensional object, and  
wherein the means for depositing the waste material also dispenses the waste material in a waste receptacle associated with the container holding a discrete amount of support material.

46. The system of claim 45 further comprising the steps of:  
means for ejecting the containers when substantially all of the material in the containers has been removed.

47. The system of claim 46 further comprising:  
means for curing the waste material after the waste material is delivered to the waste receptacle associated with the containers.

48. The system of claim 47 wherein the means for curing the waste material cures the waste material by exposure to actinic radiation .

49. The system of claim 48 further comprising:  
means for closing the waste receptacle prior to ejecting the containers.

50. A solid freeform fabrication apparatus for forming a three-dimensional object in a layerwise fashion by dispensing at least one material, the apparatus comprising:

a build environment having a build platform for supporting the three-dimensional object while it is being formed;

at least one dispensing device adjacent the build platform for dispensing the material to form layers of the three-dimensional object;

a motion means for respectively moving the dispensing device and the build platform;

means for normalizing the dispensed layers producing waste material comprising dispensed material;

a computer controller for receiving object data descriptive of the three-dimensional object and for processing the data and controlling the apparatus when forming the three-dimensional object; and

a material delivery and waste removal means for:

- a) receiving at least one container, the container holding a discrete amount of the material,
- b) removing the discrete amount of material from the containers,
- c) delivering the removed material to the dispensing device;
- d) depositing the waste material in a waste receptacle associated with the container.

51. The apparatus of claim 50 further comprising:

means for ejecting the container when substantially all of the material in the container have been removed.

52. The apparatus of claim 51 further comprising:

a waste curing means for curing the waste material after the waste material is deposited in the waste receptacle, the waste material being cured by exposure to actinic radiation.

53. The apparatus of claim 52 further comprising:

a waste closing means for sealing the waste receptacle of the containers prior to ejecting the containers.

54. The apparatus of claim 50 wherein the dispensing device dispenses a build material to form the three-dimensional object and a support material for forming support for the three-dimensional object.

55. The apparatus of claim 50 having two dispensing devices, one dispensing device dispensing a build material to form the three-dimensional object, and the other dispensing device dispensing a support material to form support for the three-dimensional object.

56. An improved solid freeform fabrication apparatus for forming a three-dimensional object in a layerwise fashion by dispensing at least one material, the apparatus of the type having a build environment including a build platform for supporting the three-dimensional object while it is being formed, at least one dispensing device adjacent the build platform for dispensing the material to form layers of the three-dimensional object and for dispensing the material in the layers to support the three-dimensional object, a motion means for respectively moving the dispensing device and the build platform, a means for normalizing the dispensed layers producing waste material comprising dispensed material, and a computer controller for receiving object data descriptive of the three-dimensional object and for processing the data and controlling the apparatus when forming the three-dimensional object, wherein the improvement comprises;

a material delivery and waste removal means for:

- a) receiving at least one container, the container holding a discrete amount of the material,
- b) removing the discrete amount of material from the containers,
- c) delivering the removed material to the dispensing device; and
- d) depositing the waste material in a waste receptacle associated with the containers.

57. The apparatus of claim 56 further comprising:  
means for ejecting the container when substantially all of the material in the container has been removed.

58. The apparatus of claim 57 further comprising:  
a waste curing means for curing the waste material after the waste material is received in the waste receptacle, the waste material being cured by exposure to actinic

radiation.

59. The apparatus of claim 58 further comprising:

a waste closing means for sealing the waste receptacle of the container prior to ejecting the container.

60. The apparatus of claim 59 wherein the dispensing device dispenses a build material to form the three-dimensional object and a support material for forming support for the three-dimensional object.

61. The apparatus of claim 60 having two dispensing devices, one dispensing device dispensing a build material to form the three-dimensional object, and the other dispensing device dispensing a support material to form support for the three-dimensional object.



62. A container for delivering unused material and for receiving waste material in a solid freeform fabrication apparatus, the container comprising:

a compartment for storing the unused material;

an opening in the compartment for removing the unused material for use by the apparatus; and

at least one waste receptacle in communication with the container for receiving the waste material.

63. The container of claim 62 wherein the compartment comprises a cylindrical syringe portion receiving a plunger having at piston end which bears against the material inside the cylindrical syringe portion and expels the material through the opening when the piston is driven into the cylindrical syringe portion.

64. The container of claim 63 wherein the plunger further comprises a sealing end opposed to the piston end wherein the waste receptacle resides between the sealing end and the piston end.

65. The container of claim 64 wherein the sealing end encloses the waste material in the waste receptacle when the sealing end engages the cylindrical syringe portion.

66. The container of claim 65 having two symmetrically opposed waste receptacles between the piston end and sealing end of the plunger.